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Catching two European birds with one renewable stone: Mitigating climate change and Eurozone crisis by an energy transition

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ABSTRACT

The threat of climate change and other risks for ecosystems and human health require a transition of the energy system from fossil fuels towards renewable energies and higher efficiency. The European geographical periphery, and specifically Southern Europe, has considerable potential for renewable energies. At the same time it is also stricken by high levels of public debt and unemployment, and struggles with austerity policies as consequences of the Eurozone crisis. Modeling studies find a broad optimum when searching for a cost-optimal deployment of renewable energy installations. This allows for the consideration of additional policy objectives. Simultaneously, economists argue for an increase in public expenditure to compensate for the slump in private investments and to provide economic stimulus. This paper combines these two perspectives. We assess the potential for renewable energies in the European periphery, and highlight relevant costs and barriers for a large-scale transition to a renewable energy system. We find that a European energy transition with a high-level of renewable energy installations in the periphery could act as an economic stimulus, decrease trade deficits, and possibly have positive employment effects. Our analysis also suggests that country-specific conditions and policy frameworks require member state policies to play a leading role in fostering an energy transition. This notwithstanding, a stronger European-wide coordination of regulatory frameworks and supportive funding schemes would leverage country-specific action. Renewed solidarity could be the most valuable outcome of a commonly designed and implemented European energy transition.

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1. Introduction

Avoiding anthropogenic climate change and risks for ecosystems and human health call for a thorough transformation of the global energy system from fossil fuels towards a more sustainable pathway [1–5].[1] Sustainability criteria translate into multiple policy targets for the energy sector, such as climate change mitigation, reduction of local environmental damages, energy security, phase-out of nuclear power plants, "green" economic growth associated with green jobs and poverty reduction, as well as maintaining or achieving a sufficient food supply. A meaningful policy analysis requires a multiple-objective, multiple-externality framework that explicitly accounts for the dynamic interdependencies [6,7] and that acknowledges potentially considerable uncertainties and the consideration of impacts that are not well quantifiable [8–10].

The European Union's (EU) climate and energy strategy rests on explicit targets for reducing greenhouse gas emission, promoting renewable energy sources and increasing energy efficiency (the so-called 20-20-20 targets). These targets have been underpinned by a variety of EU and Member State policy instruments, most notably the EU Emission Trading Scheme (EU-ETS) in the utility sector and country-specific support schemes for renewable energies. Primary measures to address these policy targets include the massive deployment of renewable energy sources, an increase in energy efficiency, and the associated changes in distribution, storage and usage patterns, shortly also referred to as energy transition [3]. These efforts notwithstanding, the political reality places the long-term challenge of climate change mitigation on the back burner. The Eurozone crisis, which involves a sovereign debt crisis, a banking crisis and a severe and enduring recession, dominates the European discourse [11]. The crisis has affected all EU Member States but particularly those in the geographical periphery. Energy transition modeling suggests that a cost-effective decarbonization of the European electricity production and distribution system can be achieved by transitioning on different pathways in terms of technology choice, spatial distribution of production capacity and the degree of connectivity between different Member States [12–14]. It is the central argument of this paper that this degree of freedom in designing an energy transition offers significant leeway to maximize welfare from co-effects of renewable deployment, thus simultaneously addressing other public policy targets than climate change mitigation. Hence, depending on its design, a European energy transition may also help European economies to recover by fostering economic growth, creating jobs, providing energy security, and building trust.

[1] RE: Renewable energies; PV: Photovoltaic; BOS: Balance of system costs; LCOE: Levelized cost of electricity; EMF: Energy Modeling Forum; TFEU: Treaty on the Functioning of the European Union; NREAPs: National Renewable Energy Action Plans; EU ETS: EU Emissions Trading Scheme; ACER: Agency for the Cooperation of Energy Regulators; ENTSO-E: European Network of Transmission System Operators for Electricity

We argue that European renewable policy should be designed such that the respective co-benefits are realized predominantly in peripheral countries. This argument rests on three rationales. 1) An argument of economic efficiency: a crash of economies in the periphery will also affect those countries that are currently well off. If the use of direct means of economic policy, such as fiscal and monetary instruments, is limited (e.g. for political reasons), the promotion of renewable energy investments in the periphery may be understood as a surrogate for such policy [15,16]. 2) An argument of justice and fairness: a joint European effort to promote renewable energy investments in the periphery may provide a fairer distribution of wealth within Europe. This is especially relevant in a unified European economy where central regions such as the Benelux countries, Germany and Northern Italy profit from agglomeration dynamics and without the periphery the center would not boast such impressive agglomeration dynamics. 3) An argument of political feasibility: co-benefits in terms of economic development or trust building may be a precondition for governments to be willing to support a European energy transition [17].

To date, the questions of how to design a European energy transition and how to help the European periphery overcome the debt crisis have been analyzed in entirely separated strands of literature. The New Economic Geography points out that in a unified economic zone, the geographical core profits at the expense of the geographical periphery due to agglomeration economics [18,19]. On the debt crisis, one strand of literature argues that deep recessions, accompanied with the bursting of property bubbles, require increased government investments to compensate for the saving demands on business [20,21]. Lending and investments into those countries that suffer most from the debt crisis are seen as most promising to elicit growth and employment effects [22]. In a very different strand of literature, the prospective of a European energy transition as driven by climate change mitigation has been explored in a recent special issue [13,23]. The technical and sustainable potential and options had already been comprehensively explored by Graßl et al. [1]. The policy status and further options were also subject to scrutiny in recent analyses [16,24]. Special emphasis has been given to the European ETS [25–28]. In a first, more holistic approach an edited volume studied the German energy transition from a behavioral economic, engineering, legal, philosophical, and political perspectives [29]. Nevertheless, a common denominator of these analyses is that they implicitly consider climate change mitigation as the predominant public policy challenge. This paper, in contrast, contextualizes a European transition of the energy system – driven by climate change mitigation concerns – in the broader framework of European challenges, notably the deep recession and debt crisis in the European periphery and its lack of solidarity. Similar to Leggewie [30], we see an opportunity in fostering renewable energies in the European periphery, an argument that we substantiate with quantitative analysis.

The scope of this paper is restricted to the analysis of electricity generation and distribution as this sector of the energy system

is currently the most dynamic one in terms of decarbonization. The outline is as follows. Section 2 investigates the technical and economic potential for renewable electricity generation across Europe, and particularly in peripheral Member States. Section 3 evaluates the potential co-effects of a European energy transition, with a special focus on which additional co-benefits could be realized by a transition that specifically targets co-benefits in the periphery. Section 4 turns to analyzing the different barriers to a (periphery-focused) European energy transition, describes measures of how these barriers could be overcome and the policies needed, and evaluates the options in regard to feasibility and accordance to different welfare perspectives. Finally, Section 5 concludes in positioning the issue of a European energy transition in the periphery into the larger context of a common project for Europe. To substantiate our analysis, we explore the specific cases of Greece, Spain, Italy, Ireland and Poland in detail, representing countries that are hit by the debt crisis and where renewable deployment would make a difference, but have quite different patterns in terms of economic activity, renewable energy resources and conducted energy transitions.

2. Potential for renewable electricity generation in Europe

As a basis for the analysis of a European energy transition, it is important to know what is the potential for electricity generation from renewable energy (RE) across Europe, and particularly in its periphery? Potential estimates need to be differentiated between the technical, economic and market potential [25]. The technical potential refers to the theoretical amount of renewable electricity generation that could be obtained with the best available techniques under given natural conditions and using the maximum available land area, irrespective of cost considerations. The economic potential is defined as the socially optimal benchmark deployment level of renewable technologies when all corresponding social costs and benefits, including negative externalities and co-benefits, are taken into account. The market potential is the amount of renewable energy use that market participants pursue as investments under given market conditions.

The following elaborates on the underlying argument why the deployment of RE technologies in the European periphery can be a cost-effective and -efficient solution to decarbonizing the European electricity system. Section 2.1 elaborates on the abundant technical potential of wind and solar energy in Europe and discusses prospects of technology development. Section 2.2 explores model-based estimates of the economic potential of RE and discusses issues that are not, or cannot be represented in the models but may be highly relevant for assessing the effects of a European energy transition.

2.1. Technical potential and technology costs

The most important RE electricity generation technologies in Europe are based on solar irradiation (i.e. solar photovoltaic and solar thermal power plants), and wind energy, both onshore and offshore. Biomass, hydro power and geothermal energy also play a role; however, their potential is regionally limited and in the case of biomass also subject to land competition with food production and biodiversity. From a resources point of view, a fully renewable electricity system in Europe is possible, as the technical potential of RE is abundant [31]. In order to visualize the regional distribution of solar irradiation and wind energy, Fig. 1 illustrates annual full load hours of wind turbines and solar photovoltaic (PV) modules based on meteorological data and specific technology assumptions. Even though full load hours may be higher in the future due to technology advancements, a distinct pattern emerges: wind potentials are the highest in the northern periphery and solar potentials are particularly high on the Iberian Peninsula, Italy and south-eastern Europe.

Wind is in many situations, but depending on the remaining availability of hydro, currently the most cost competitive renewable energy technology in the electricity market. The levelized costs of electricity from wind energy are between 4 and 8 €c/kW h in many locations [35,36]. Offshore wind installations are currently more expensive, but are experiencing a steep learning curve [36]. The total cost of onshore installations is mostly determined by the turbine price itself (ca. 80% of total costs), while operations and maintenance account for about 1.2–1.5 €c/kW h. Hence, the profitability of wind energy mainly depends on the availability of wind. The profitability threshold is usually assumed to be around 2300 full load hours [36] (cf. Fig. 1). At high penetration levels of wind power of 40% or higher, costs for grid expansion and reserve capacity become important, but are not well estimated [36]. EEA [36] summarizes grid extension costs to be anywhere between 0 and 10 €c/kW h, and costs for reserve capacity at 2–4 €c/kW h. Overall, wind energy is often cost-competitive without subsidies. The technical potential would allow for an increase of about 2 orders of magnitude compared to current deployment levels, theoretically satisfying current electricity demand (Table 1). In practice, local environmental impact due to the installation of operation of wind turbines, however, cannot be ignored [37], leading together with local protests and economic consideration to considerably lower projected deployment rates (see Section 2.2).

The technical potential for bioenergy in Europe is significantly below that of wind energy but potentially highly relevant for future bioenergy supply (Table 1, [38]). Within Europe, Romania, Bulgaria, Ukraine, the Baltic States and Poland might have the highest potential at low costs [38]. Costs of biomass vary between European countries, with feedstock, climatic and geographic conditions, and the state of supply chain logistics: 5–15 €/GJ for current food-based biofuels with possibly lower costs for residues and dedicated bioenergy crops [38]. Under ideal circumstances, electricity from biomass is cost competitive with electricity from fossil sources, but prices remained above 20 €c/kW h in 2012 [39]. Its most significant role is as a flexible fuel counterbalancing intermittency from other renewables. In many cases biomass still builds on mandates or monetary incentive to be supplied in energy systems. As land availability is a limiting factor, higher demand results in higher prices on feedstock, while supply chain logistics experience notable learning curves, i.e. reduce prices.

The global warming impact of bioenergy remains uncertain with inductive studies pointing to relevant life-cycle emissions in the short run, whereas global integrated assessment models indicate the potential for bioenergy for climate change mitigation [40]. Life-cycle emissions and climate change mitigation effects are highly variable, and depend on fertilizer application, land use change effects, yields, and market-mediated effects. Guaranteeing food security and the protection of biodiversity can constitute additional constraints on bioenergy deployment.

The technical potential of solar energy based electricity generation appears to be no practical limitation to a European energy transition. In the EU, on average a photovoltaic module area being equivalent to 0.6% of a country's surface area is sufficient to deliver the country's complete electricity consumption [41]. This potential shrinks if only rooftop installations and installations near or on sealed land are considered as indicated in Table 1. The dominating technology to harvest this huge potential will be photovoltaics. The costs of electricity from solar photovoltaics very strongly depending on the used technology, system size and country of deployment. As a global trend, however, electricity from photovoltaics has become continuously cheaper over the last decades. The costs can be split into two major cost components: the costs for PV modules on the one hand, and on the other hand the

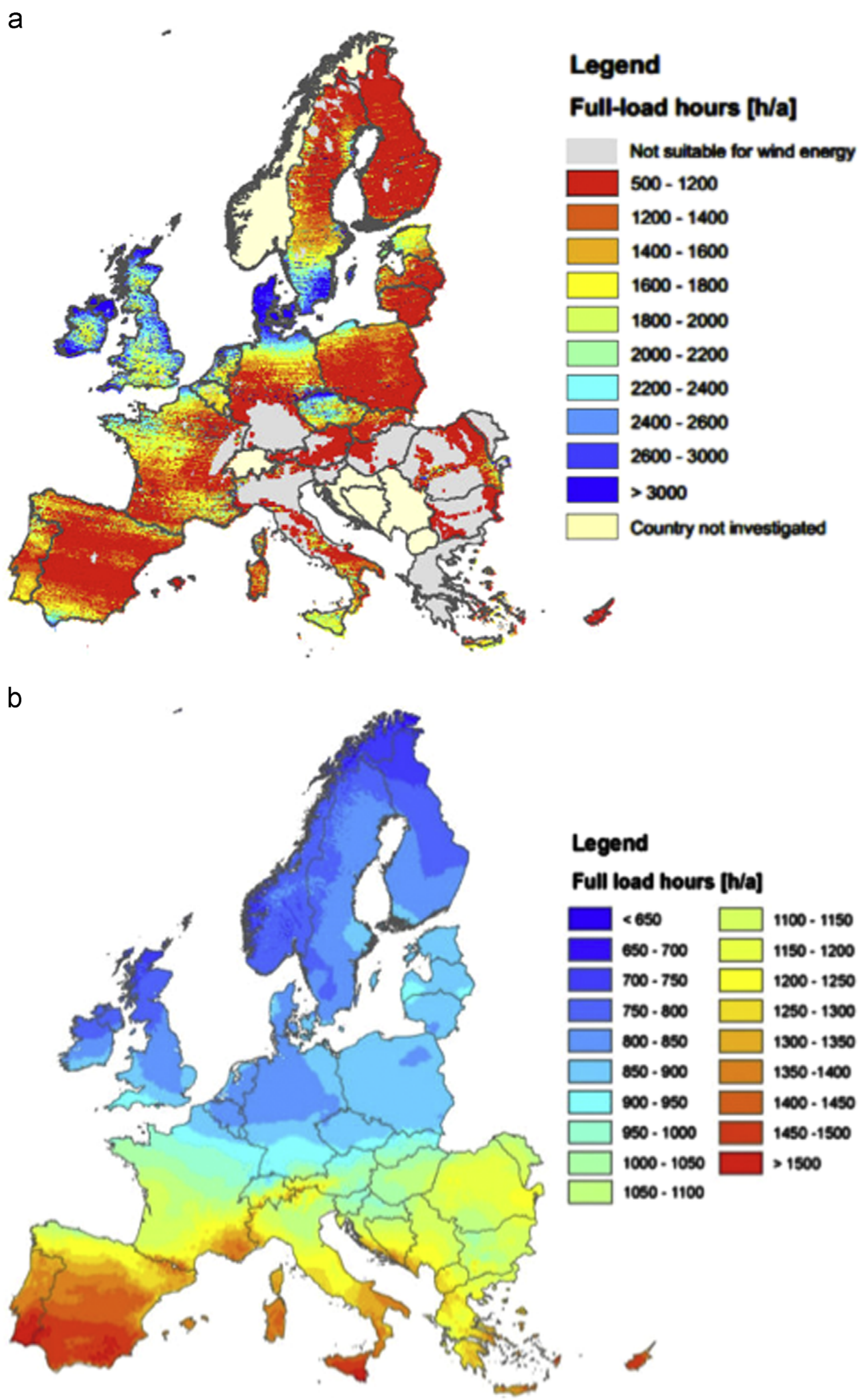

Fig. 1. Annual full load hours of wind turbines (left) and optimally inclined PV modules (right). Source: Figures 4 and 5 and 4–10 in [32] and reproduced in [33]. Some of the area judged to be not suitable for wind energy might still show substantial potential [33,34].

additional costs to plan, market, and construct a complete system comprising photovoltaic modules, inverters and other components all summarized as balance of system costs (BOS). PV modules are traded on a more or less global market. Since 1979, global average module prices decreased with a learning rate of 22% (22% price reduction for each doubling of cumulative volume) for the dominating crystalline silicon technology [42], with current (September 2013) average prices on the European spot market between 0.58 €/Wp and 0.74 €/Wp,[2] even below that historic trend. In contrast learning

[2] Wp (Watt Peak) is commonly used in the PV field to describe the size of PV systems. A module with 1 Wp would deliver 1 W power output under standard test conditions.

Table 1
Electricity from Renewables and Potentials in six EU member states. The electricity consumption of six EU member states and their year 2011 electricity trade balance is shown in the top two rows. The following three blocks describe in three rows each the countries' current electricity production per renewable energy source, its technical potential and the current production as the percentage of potential. (a) The final electricity consumption defined by the IEA excludes energy industry's own use. (b) The 2012 Wind Power Share denotes the electric energy that the wind power installations by 2012 would produce in a meteorologically normal wind year [35].(c) The estimation of technical potential for electricity from wind is based on seven different land covers and their respective suitability for wind power installations, and average wind speed distributions. Environmental factors and social preferences are not taken into account. When accounted for designated nature areas, the technical potential reported would decrease by 14% on an European average [36]. (d) The bioenergy potentials are based on Ref. [37]. A conversion factor of 1/3 from biomass to electricity is assumed. (e) The 2012 Technical PV potential is calculated based on Braun et al. (2012), using population and infrastructure-based estimations of PV capacities. These are applied to country-specific solar PV yield data of Breyer and Schmid (2010). The technical potential for PV reported here only assumes use of readily available surfaces, such as on roofs or closely along motorways. This estimation is much more conservative than the one used for wind energy.

			Greece	Ireland	Italy	Poland	Spain
	2011 final electricity consumption	TW h yr^{-1} (*IEA 2011*) (*a*)	52	25	302	122	234
	2011 electricity trade balance (%)	*As share of final consumption (IEA 2011)*	−6	−2	−15	4	2.6
Wind	2012 wind power penetration (%)	*Final consumption* (*EWEA 2012*) (*b*)	6	13	5	3	16
	2030 technical wind electricity potential	TW h yr^{-1} [36](*c*)	1430	2350	2150	4000	3150
	Technical potential used in 2012 (%)	*Share of 2030 potential*	0.22	0.14	0.70	0.09	1.19
Biomass	2011 electricity from biomass	TW h yr^{-1} (*IEA 2011*)	0.21	0.34	8.63	7.60	3.81
	2030 technical potential	TW h yr^{-1} (*d*)	13	6	44	132	68
	2030 technical potential used in 2011 (%)	*Share of 2030 potential*	1.6	6.1	19.8	5.8	5.6
Solar PV	2011 electricity production from solar	TW h yr^{-1} (*IEA 2011*)	0.6	0.0	10.8	0.0	8.7
	2012 PV technical potential	TW h yr^{-1} (*e*)	119	35	429	241	516
	Technical solar potential used in 2011 (%)	*Share of 2012 potential*	0.5	0.0	2.5	0.0	1.7

rates for BOS differ by country being about 15% in Germany and 7% in the United States [43], reflecting among other reasons different administrative conditions for the deployment of photovoltaic systems. Together with different market maturities (cumulative installed photovoltaic capacity), this results in a wide range of BOS with the global average of 1.19 €/Wp being nearly double as high as best cases in the range of 0.6 €/Wp, which are realized with utility scale ground mounted systems in Germany [42]. The resulting levelized cost of electricity (LCOE) in turn depend on the cost for capital reflected in the calculatory interest rate and the specific yield, which is the amount of generated electricity for one year divided by the system's capacity. This results into a situation in which LCOE in mature markets like Germany can be comparable to LCOE in southern Europe, where higher specific yields (more sun) are offset by higher BOS and higher capital costs [44].

2.2. *Economic potential estimates*

It is clear that the full technical potential of any renewable energy source can hardly be used under realistic circumstances, that is, when economic and sustainability constraints are accounted for. Economic potential estimates are usually pursued by means of large-scale models of the European energy system and macro economy. In the 28th round of the model intercomparison exercise Energy Modeling Forum (EMF28), 13 different models have been employed to calculate scenarios that lead to an 80% greenhouse gas emission reduction in 2050 relative to 1990. A robust conclusion across all models is that the variable renewable energy sources wind and solar will both have a substantially larger role to play, with a median share of 27% in the European electricity sector for the year 2050 [13]. This share even increases up to 37% if CCS is not available and up to about 50% if in addition no new nuclear power plants are being built. A more detailed analysis of individual countries technology mixes in the electricity sector reveals that they differ significantly across countries and largely depend on the type of renewable potential that each country is endowed with [23]. However, a common denominator of the energy system models employed in the EMF28 model comparison exercise is that they do not explicitly consider infrastructure requirements [13,23]. The EMF28 scenarios have also been analyzed with dedicated infrastructure models [45]. In this context Egerer et al. [46] find with a line-sharp model of the European transmission grid that more that around 50,000 km of pan-European transmission lines need to be built or upgraded for achieving a cost-efficient system.

A particularly important driver for transmission infrastructure expansion is the location of renewable electricity generation capacities. Schmid and Knopf [14] show that different assumptions on the development of specific investment costs for wind and solar technologies lead to substantially different configurations of a cost-optimal decarbonized European electricity system in the long-term future. Fig. 2 illustrates average annual power flows in 2050 in two scenarios that allow for a high expansion of transmission capacities between ENTSO-E regions but with differing assumptions for the investment costs of wind and solar technologies: once with values set to the middle of the range reported in the literature, and once with optimistic cost development assumptions for solar technologies (which appears to be plausible given the discussion in Section 2.1), and pessimistic ones for wind technologies. In the first case it is particularly the wind resources in the north-western, northern and eastern European periphery that generate a surplus of electricity that is imported to central Europe. In the second case the pattern changes significantly – here it is particularly the solar resources of the Iberian Peninsula and South-Eastern Europe that are exploited and transported to central Europe.

Schmid and Knopf [14] find for a set of scenarios that the increasing integration of the European electricity system by means of transmission capacity expansion leads to a reduction of total system costs of 2–3.5% over the period 2010–2050, confirming earlier results that grid integration is a no-regret option for Europe as a whole. This finding is robust across scenarios that are based on different assumptions on the development of investment costs for wind and solar technologies. The basic logic is that, once pan-European transmission capacities are expanded, the cost-optimal location of wind and solar capacities shifts to comparatively more favorable resources in the European periphery. Whether the “Northern solution” based on wind energy or the “Southern solution” based on solar energy is more cost-optimal will depend on the comparative development of their investment costs. The implications of different pathways for individual countries would be substantial. This includes issues such as 1) dependence on other countries (e.g., in the transmission expansion scenario some countries turn into net importers); 2) change in domestic technology mixes; and 3) modified capital requirements of individual countries for renewable investments. From a global perspective,

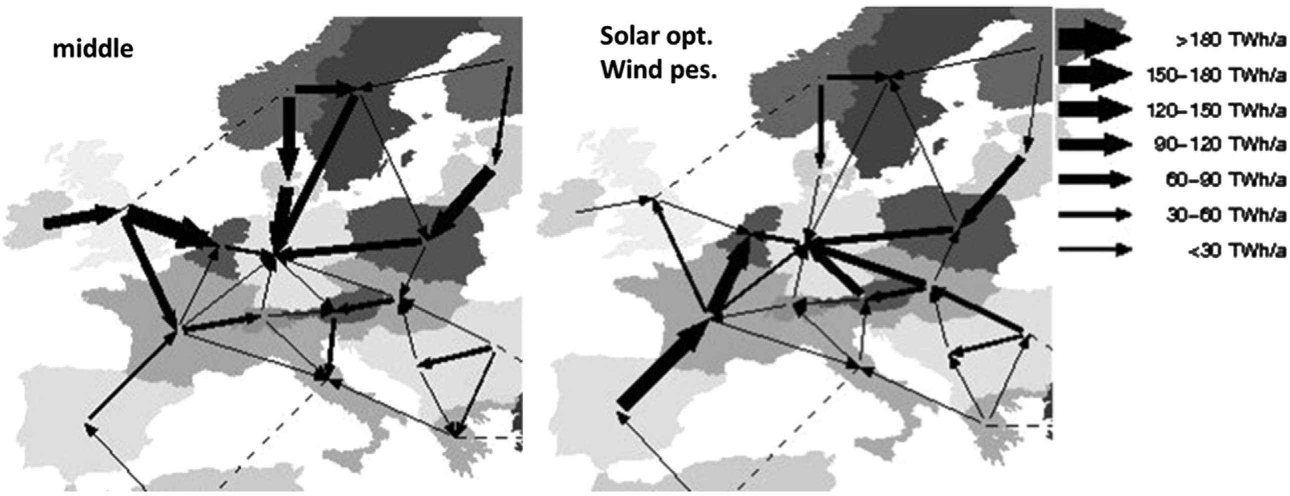

Fig. 2. Average annual net electricity flows between ENTSO-E regions in the year 2050 for two scenarios with high transmission capacity expansion between regions and different assumptions on the development of investment costs for wind and solar technologies, i.e. middle of the range in the literature (left) and solar optimistic/wind pessimistic values from the range in the literature (right). Source: Figure 5 in [14].

however, the costs are not overly sensitive with respect to the design of the European electricity system in terms of transmission corridors and the choice of which renewables potential to tap into. Considering that the illustrated pathways are designed to be primarily optimal with respect to the policy objective of climate change mitigation, it seems therefore worthwhile to explore further what the externalities of increasing RE deployment are with respect to other public policy objectives related to sustainability. Such an analysis would allow exploiting the broad optimum to simultaneously achieve such other objectives.

However, quantitative energy system models are bound to simplify the energy system in order to remain numerically tractable and are only able to consider effects that are quantifiable after all, and thus do not consider most of these externalities. Furthermore, estimates of the economic potential of RE are strongly dependent on underlying assumptions. While there is a multitude of issues, the following discussion concentrates on specific quantifiable and non-quantifiable effects that are of particular interest for a European energy transition.

The most important aspect that is either neglected or represented in very simplified terms is the variability of wind and solar both on the temporal and geographical scale [6]. Time scales are mostly coarsely specified. Many energy system models possess limited means to deal with fluctuations. Instead these fluctuations are usually represented by characteristic days or comparable concepts (e.g. a fixed share of flexible gas power plants per RE capacity). The geographical resolution is usually confined to model regions in the size of countries that exhibit significant intra-regional variability, with beneficial or detrimental correlations in terms of balancing requirements. Other options to balance production and demand than grid interconnections are usually neglected (e.g. special configuration of solar modules, virtual power plants of decentralized dispersed combined heat and power plants and especially demand side management). The major reason for their omission is most likely the crude geographical scale and the lack of explicit consideration of individual actors. New electricity planning models, however, allow fine-grained considerations of both temporal intermittency and spatial variation [47,48], pointing tentatively to higher renewable-share potentials, though these models have not been validated for Europe.

A range of issues that is not directly quantifiable may remain beyond modeling exercises. The non-quantifiability arises on the one hand due to a lack of theoretical concepts to describe the effects in stylized models, and on the other hand due to non-observability of the data. Three issues seem particularly important: (a) the wider macro-economic impact of RE deployment, (b) employment effects and (c) energy security. Due to their focus on the energy system, such models represent macroeconomic processes only very crudely, if at all. But the renewables industry does not act in isolation; especially on a regional or local level the public policy objective of climate change mitigation often has lower priority than employment, energy security or direct environmental effects.

3. Evaluating welfare increase induced by co-effects of an European energy transition

If an energy transition focuses RE deployment in the periphery, particularly in southern European countries, the benefit and cost distribution could be such that the economic debt crises could be effectively mediated. In the following, we analyze this argument in more detail.

3.1. Stimulus effect of RE deployment in the periphery

Besides positive environmental effects related to reductions in GHG emissions, increased spending on RE infrastructure could potentially have the effect of an economic stimulus. The idea that economic slumps can to at least some extent be remedied by fiscal policies is a cornerstone of Keynesian macro-economics and has regained prominence in the recent financial and economic crisis, in which the world's major economies have enacted stimulus packages to revive their economies. The basic premise of this theory is that an economic downturn is first and foremost a consequence of a shortfall in demand, and that it can be tackled by reviving demand through either lowering taxes or increasing public spending. It has been suggested that it would be advantageous to target activities that not only have a stimulus effect, but also yield environmental benefits [49–51]. Related literature suggests that a deep recession, characterized by a debt crisis, triggers saving efforts in the private sector [21,52,53]. An expansion of the public sector can then prevent the long continuation of the recession. Understanding infrastructures as the template and basis for economic activities, targeted public investments in

infrastructure construction and maintenance can be most productive [52–54].

The respective literature identifies several criteria for stimulus spending to have a positive effect on growth. First, they exhibit their most pronounced positive effect when the economy is in a slump, while they are less effective in a growing economy [55–57]. Second, the associated fiscal multipliers – i.e. the expansion of output as a reaction to an increase in demand (either through tax cuts or additional government spending) – are largest if interest rates are (very) low [58] and in the presence of a financial crisis [59]. Third, stimulus measures are found to be more effective if they rely on additional spending instead of tax cuts [60]. More pronounced positive effects of stimulus measures should be expected if the additional spending keeps government debt within certain boundaries. Otherwise, high debts might undermine investment incentives due to expectations of a deteriorating business environment [61,62].

Arguably, all the above conditions hold for the case of increased investment in RE in the EU periphery. The corresponding countries are by 2013 still experiencing economic recessions. Interest rates remain low, while the banking system is severely weakened. The discussed infrastructure investments would hence boost public spending, and – if their costs were covered by countries from the core (for financing see Section 4.2.2) – would not increase government debt. Reviewing a total of 37 empirical studies, Baunsgaard et al. [60] find that under such conditions, observed fiscal multipliers range between 0 and 2.1, with a mean of 0.8. Of course, the described effects are not uniform across countries, and detailed country-specific studies would be required in order to understand the conditions that have to put into place to achieve the most in terms of stimulus [56].

In terms of volume, RE investment could be of an order of magnitude that yields noticeable effects on economic activity. For instance, spending on FiTs for RE in Germany in 2012 amounted to about 0.6% of GDP.[3] This figure is comparable to the 0.5% of GDP targeted at infrastructure investment in order to kick-start growth in the EU proposed in a recent proposal by Griffith-Jones et al. [22] whereas the stimulus packages enacted in the EU during the period 2008–2010 amount to about 2% of GDP [63].

Perhaps the most substantial concern regarding the stimulus effects of increased spending on RE concerns the timeframe in which they can be carried out: as few RE projects are ‘shovel ready’, they might require several years of planning and investment. Hence, policies aiming to achieve short-run should focus on projects that can be put into practice relatively quickly (solar PV, for example, can be built relatively fast). However, also projects with a longer ramp-up phase could help to overcome the recession, as the latter is not merely a short-term fluctuation of the business cycle, but rather a structural crisis that can be expected to last for several years. Hence, increased spending on RE could contribute towards improving long-term growth prospects in the periphery.

3.2. Employment effects

Evaluating the labor market effects of renewable energy policies in detail is a challenging task that requires an assessment of how value chains and production patterns adjust in the mid-term and how structural adjustment and innovative activity respond in the long term. Results depend on (a) the assessment of positive employment effects (consideration of the electricity sector only or the renewable energy sector in general including also heat systems and biofuels; assumptions about foreign trade effects), (b) the assessment of negative employment effects (crowding-out effects only or budget effects as well), and (c) the time horizon of the assessments in general. A comprehensive assessment of these effects is missing so far and numbers from different studies are often not comparable with each other as they consider different aspects. Nonetheless, we summarize here some studies that refer to the employment effect of RE.

One study finds that under the ‘Energy(R)evolution’ scenario developed by Greenpeace, which sets a target of reducing global GHG emissions by 50% below their 1990 level by 2050, 500,000 additional workers will be employed in the energy sector of the EU27 compared to the business-as-usual case [64]. A very similar figure is obtained by Ragwitz et al. [65], who assume a 20% share of renewable energy in the EU's final energy as stated in the Renewable Energy Directive for 2020. Under this scenario, Greece is projected to have an employment gain of roughly 1% and Spain of 0.6%, while Ireland only sees a negligibly small but still positive impact on employment. Most additional jobs are created in industrial manufacturing sectors. These numbers also agree well with the order of magnitude found in analysis of current employment on national levels and globally [66–68]. For example, a typical number of 11 thousand employees per installed GW of PV electricity is found in Germany in several studies in a very rough analysis, simply dividing the number of full-time equivalent jobs associated with the complete German PV sector by the number of GW installed in the same year (2012) [66–68]. On a global scale the same indicator is even four times higher [68].

As policies that increase the share of renewables may lead to rising electricity prices, job gains in the energy sector have to be weighed against potential job losses in other sectors. For instance, while energy-intensive industries are mostly exempted, and actually benefit from lower electricity prices, household electricity prices in Germany had already risen by 5% in 2009, which can be partly attributed to the Renewable Energy Law [69] and have since increased markedly for several reasons, including the increasing share of renewable energies and increasing numbers of exemptions from the support payments for industries. Ragwitz et al. [65] estimate that reaching the EU's 2020 goals might entail electricity price increases of on average 2.2%, concluding that these increases should not have substantial negative effects on the EU's industrial structure. These costs could further be lowered if EU member states harmonized their support of renewables in order to exploit potentials cost effectively (the total annual costs of renewable energy deployment could be lowered by about €10 billion if member states traded energy as a good in a single European market instead of national markets [70]).

These considerations notwithstanding, the empirical evidence on net employment effects is mixed. Some confirm a significant increase in employment [71,72], while others find zero or negative effects [73,74]. Crucially, equilibrium effects on employment depend on the revenue source and/or the counterfactual spending (see also Section 4.2). For example, if financed by labor taxes, economic models suggest that RE subsidies decrease employment and welfare [75]. Overall, a comprehensive assessment of the net effects of RE deployment is lacking; arguments for RE policies based on employment effects are subjects to considerable uncertainty and ignorance. Hence, RE policies as such should not be regarded as an appropriate means to remedy underlying distortions in the labor market. Yet, if conducted as part of a stimulus measure, it makes good economic sense to consider employment effects of such policies, as the unemployment can be attributed to a shortfall in demand rather than labor market frictions.

[3] As part of the Energy Roadmap 2050, the EU Commission has assessed that a shift from reference scenarios with existing policy measures to low-carbon scenarios would require €260 billion in annual average incremental investments over 2010–2050, which is equivalent to 2.1% of 2008 EU GDP (however, it should be noted that the largest part of these investments are projected for energy efficiency measures).

In such a situation, measures to boost employment can improve an economy's long-term growth potential, as they e.g. reduce the depreciation of human capital occurring under long-term unemployment (which could lead to 'hysteresis', i.e. the economy not returning to its previous potential output after a crisis) [76].

3.3. Energy security

Covering a higher share of domestic energy consumption can also have bearing on a country's energy security. In its broadest sense, energy security refers to the uninterrupted provision of vital energy services [5], or from a system perspective to robustness against sudden disruptions of energy supply [77]. Building on these concepts, three particular dimensions of energy security have been identified: A) depletion of exhaustible resources; B) import dependence; and C) variability and reliability of energy supply at affordable costs [3]. In turn, these dimensions are influenced by a number of factors, in particular the portfolio of power plants (fuels, capacity), transmission lines, storage and demand.

We discuss each of three dimensions of energy security in turn. Any policy to increase the share of RE will reduce the depletion rate of exhaustible resources, especially in the presence of a carbon tax or a tightened ETS. In other words, RE deployment in peripheral countries will contribute to prolonging the life-time of existing deposits of exhaustible resources and dampen the rise of extraction costs by avoiding the need to tap low-grade, high cost reserves of coal and gas.

Addressing the import dependence, some periphery countries are net importers of about 2–15% of their electricity consumption (especially Italy, and to lesser degree Greece and Ireland see Table 1). RES support may help to increase the share of domestic generation in these countries – and even convert them into net exporters of electricity. This would support lowering current account deficits, which for Greece and Portugal amounted to more than 6% in 2012 [78]. In addition, an increase in RES generation typically crowds out natural gas and oil-fired power plants, the fuels for which are often imported from outside the EU [79,80].

Third, due to their fluctuating time profiles, higher reliance on RE could negatively affect grid stability, especially if large shares of total electricity are met by RE. This is a very relevant risk and applicable for RE deployment without a comprehensive system transition. Complementary and necessary system measures would include investments in storage and back-up capacities, which, however, would involve additional costs during the transition. In fact, a detailed study demonstrated that energy security is possible with 100% RE if well integrated with storage units and energy-savings measures even on the national level [81,82]. Moreover, this transition, once completed, would deliver electricity at similar costs as the existing energy supply [81]. On the other hand, closer integration of the European electricity grid would not only lower costs by means of reaping gains from trade, but would also increase reliability of electricity supply, as – at least on average – regional fluctuations would cancel out on a larger scale. Increasing transmission capacity is particularly important for the peripheral countries investigated (especially for Poland, Ireland and Spain, and to lesser degree for Greece, Italy), which display the lowest ration of interconnection capacity over peak load (Fig. 4 in E3G [83]).

For the EU, the perceived dependence on Russian gas might increase the desirability of RE if integrated with the heating sector. But generally, while RE can contribute to energy security, depending on the overall system design, the comparative advantage of RE lies in its environmental benefits rather than in its potential to increase energy security [84].

4. How to promote an energy transition in the European periphery?

4.1. Barriers to renewable deployment

In principle, support schemes have been implemented in virtually all countries in the periphery to address barriers to RE deployment. The EU also provided an option for bilateral agreements between Member States to spur RE deployment (see Section 4.2). These efforts notwithstanding, significant barriers remain.

The cooperative mechanisms established by the EU have hardly been made use of – either because Member States are unlikely to be sanctioned if their RE targets are not met, or because their targets are not very ambitious and can be easily attained by domestic measures [85,86].

More importantly, important barriers still prevail at the Member State level. To evaluate barriers to RE deployment, we report and categorize these barriers in selected recession countries (Table 2). We find that economic and administrative barriers are the dominant obstacles for RE deployment. In the economic domain, the financial crisis exacerbated financing challenges as governments reduced support policies. For instance, in Spain and Italy, the crisis intensified the slowing down of the RES development. In Spain, poorly designed policies based on subsidizing programs through high feed-in tariffs have increased the difference between utility payments to renewable power producers and revenues utilities collect from customers annually [34,87]. In consequence, the national government restricted incentives. In 2013, Spain and Italy eliminated subsides to renewable production [87,88]. Legal uncertainty has also influenced rating agencies to downgrade tariff deficit securitizations. Consequently, the current lack of predictability has been translated to market instability. Often the high initial capital investments are discouraging for investors. In addition, in some countries (e.g., Poland and Spain) taxation regimes further disincentive investments into renewables [89].

Administrative obstacles constitute the second important category of barriers (Table 2). Many projects suffer delays due to a lack of harmonization in legal frameworks, trading schemes and administrative procedures; regulatory and administrative issues impair the RE development. In many countries of the European periphery the lack in the national regulatory framework provokes an asynchrony in receiving authorizations. The high number of administrative bodies involved in the approval procedures for the installation also lengthens the process [34,89,90]. By the same token, the complexity and lack of standardization of environmental procedures also limits RE projects (e.g., Italy and Poland). Such administrative hurdles contribute to deterring investors [89]. The spread of PV deployment costs between Germany and some Southern Europe countries, such as Greece, is most likely due to the difference in bureaucratic costs and other soft costs.

Important barriers are also related to infrastructural limits. In some cases, lack of transmission capacity hinders installation of RE (e.g., Italy, Ireland and Greece). In other cases, the transmission lines need to be extended or modernized. In addition, political and social conflicts (e.g.; the not-in-my-backyard (NIMBY) syndrome) prevent the development of RE. Finally, policies for RE deployment often compete rather than co-operate with environmental protection and land use and face community acceptance problems [34,89].

4.2. A multi-level implementation strategy with a stronger role for the EU

A European energy transition would profit if Member States in the periphery implemented national measures to address the barriers outlined above more properly. Exemplarily for the large

Table 2
Country-specific barriers for the RE development in European periphery. Full circle: the issue is crucial for the country. Empty circle: the issue is relevant for the country. Dash: the issue has no relevance for the country.

Country	Issue	Economic constraints	Infrastructural constraints	Regulatory & administrative framework	Community acceptance	Incompatibility with other policies
Italy	Regional inhomogeneity in the procedures, especially in environmental ones, high capital costs related to landscape policies and administration fees (8–12% of the total costs) and high number of administrative bodies involved – that provoke long authorization processes and asynchrony in receiving authorizations – discourage investors [86,87]. Environmental groups and Regions oppose the installation of onshore wind turbines to not alter the natural landscape. For offshore wind turbines, constraints come from the depth of the coastal water [88].	●	○	●	○	●
Poland	Often large initial capital requirements prevent the development of RES. The installation of photovoltaic panels is limited to special purposes and in most cases these are not connected to the grid [86,89]. For RES in buildings, low financial support available for individuals and lack of information lead to low RES installation. Historical and public buildings do not often include RES technology, showing a lack of exemplary action [86]. Transmission lines are often obsolete and insufficient. The Energy Law is not clear about the sharing between investors and TSO for their modernization. Operators are not obliged by any legal regulations and nor stimulated by any financial incentive to invest in the modernization and expansion of the grid. Landowners are not willing to permit the lines to be built up on their properties [86]. The procedural, administrative and regulatory frameworks are fragmented, since the RES sector is regulated by numerous executive supplements to the Energy Law. This provokes asynchrony in receiving authorizations, lengthens processes and discourages investors, e.g. when hydropower, biomass and small power plants are evaluated. The procedures for small power plants are as complex as those for large plants. Environmental procedures are complicated and non-standardized. RES compete with environmental protection and land use policies. Resistance of local authorities to RES results in a lack of regional planning and public support [86].	●	●	●	○	○
Spain	Legal framework shift from subsidizing to restrictive leads to market instability [84]. Infrastructure development – mainly distribution network and grid connection – is affected by regional inhomogeneity and inefficiency in administrative procedures, and the large number of administrative bodies involved. This lengthens the authorization process and subsequently discourages investors [34,86].	●	○	●	–	–
Ireland	Feed-in tariffs have an upper capacity limit, which is far exceeded by the number of applications for grid connections. The number of subsidized filed projects is uncertain [34,86]. Important infrastructural barriers, mainly concerning transportation grids, limit the RES development. Additionally, Ireland and the European Continent are not directly connected [86].	●	●	–	–	–
Greece	Grid congestion problems exist in locations with high RES potential. Greek islands are excluded from any RES project because they are not connected to the main grid due to capital constraints and the great depth of the Aegean Sea. Complicated administrative procedures and multiple authorities involved – interpreting law in different ways – cause authorization delays. A national lack of communication and awareness provokes local opposition [86]. Lack of experience (procedural expertise) in obtaining financial support from the EU community is perceived as a barrier to RES development (personal communication Argyropoulos, D., 2013).	●	●	●	○	–

Table 3
Policy instruments at EU and Member State level to address barriers to RE generation, grid extension and storage and demand response

	EU policies		**Member State policies**
	Strengthening the regulatory framework	**Financing**	
Generation	• Setting a separate RE target for 2030 • Promoting the use of cooperation mechanisms for renewable energy policy • Employing the open method of coordination for RE policies • Strengthening the EU Emissions Trading Scheme by setting ambitious GHG reduction targets for 2030 • Increasing minimum tax rates for non-renewable fuels • Promoting the internal energy market • Transfer of administrative procedures, skills and arrangement of financing schemes	• Allocating a higher share of EU ETS auctioning revenues to Member States in the periphery • Targeting loans of the European Investment Bank (EIB) more strongly to renewable energy investments • Targeting loans under the European Investment Fund (EIF) more strongly to small and medium-size enterprises in the field of renewable energy • Targeting the European Regional Development Fund (ERDF) and the Cohesion Fund more strongly to renewable energy investments	• Governments endorsing explicit deployment scenarios • Providing and modifying support policies for RE deployment, e.g. low interest rates for investments, and generation subsidies • Phasing-out adverse subsidies/increasing taxes for fossil and nuclear fuels • Implementing transparent and participatory planning processes, e.g., including zoning of priority areas • Standardizing binding permitting procedures for renewable energy investments with one-stop contact points for investors • Waiving administrative fees for permitting renewable energy investments • Compensation schemes for local external costs of RE investments
Grids	• Ensuring network interoperability by common guidelines • Harmonizing Member States' diverse technical standards • Strengthening the competencies of the Agency for the Cooperation of Energy Regulators (ACER) • More transparent planning process for grid development	• Providing financial support via the Cohesion Fund	• Shallow connection charges plus differentiated network use of system charges to provide locational signals • Stronger regulatory incentives for investment and innovation
Storage and Demand response	• Common EU-wide standards for smart meters		• Dynamic electricity pricing for customers • Time-variant grid fees and taxes • Lower entrance barriers to ancillary markets, e.g., smaller bid size in balancing markets • Large-scale support for infrastructure development (smart meters and grids)

body of literature, Lehmann et al. [91] provide an overview of instruments, which could be employed to spur an energy transition. Policies can address three categories: RE generation, grids, and storage and demand response. A coordination of these different categories is crucial as energy investments are strongly path-dependent, i.e. sub-optimal investment decisions taken today are perpetuated over a long period of time [16,92,93]. Country-specific options are briefly summarized in the right column of Table 3.

In the light of the Eurozone crisis and the associated budgetary limits – but also due to institutional constraints – it is highly unlikely that most Member States in the periphery will be able to overcome the barriers in the short term by themselves. As a consequence, a strong(er) enabling policy framework at the EU level could support an energy transition. For example, a uniform European feed-in tariff including an EU-wide compensation scheme could be proposed. However, such schemes would need to be adapted to and coordinated with local and national circumstances and policies. Well-intentioned top-down schemes are bound to fail if opposing local civil society is ignored [94] [29]; an exclusively top-down European approach for energy policy is neither economically justifiable nor legally and politically feasible.

The analysis in 4.1 suggests that 'soft' bureaucratic costs of RE deployment may explain the relatively high costs in some Southern European countries. Providing funds for overcoming this cost barrier (e.g., human capacity building; designing streamlined bureaucratic procedures) could make RE deployment more cost-competitive and bring LCOEs down to those in front-runner countries.

From an economic perspective, the following arguments can be put forward in favor of a certain degree of decentralization in energy policy. First, the theory of fiscal federalism [95–97] suggests that co-benefits (and co-costs) of RE deployment that are realized at the local or regional scale are more likely to be addressed properly by policy approaches taken at the same scale, such as regionally differentiated RE schemes [98]. Second, technology preferences and geographical conditions – and accordingly the assessment of related costs and benefits of different options – may vary across regions, and may explain the heterogeneity of technology choices observed across Europe [13,23]. Third, if the actual performance of policy approaches is subject to uncertainty, regulatory diversity and competition may promote institutional and policy innovation and diffusion [95,97,99], and even lead to bottom-up policy convergence over time as observed in the EU [100,101].

From a legal perspective, it has to be pointed out that the current European legal framework impairs a full harmonization of energy policies across Member States [102]. On the one hand, Article 194 of the Treaty on the Functioning of the European Union (TFEU) mentions energy policy as a field of European responsibility, following inter alia the principles of environmental conservation and solidarity across Member States. On the other hand, however, the same Article also clearly emphasizes that the competences regarding the exploitation of energy sources and the choice and use of energy technologies reside with Member States. It will need strong political will to strengthen EU competencies in the short- or mid-term as Member States usually have a strong interest in maintaining their energy policy sovereignty to protect their national energy technology mixes and energy security at the national level.

Consequently, a pragmatic strategy to promote RE deployment and generate related benefits particularly in the periphery has to rest jointly on European as well as Member State activities. Against this background, we see two particular avenues for the EU to promote an energy transition in the periphery: strengthening the regulatory framework for Member State policies and providing funds. These avenues are briefly outlined in the following and also summarized in Table 3.

4.2.1. *Strengthening the regulatory framework for an European energy transition*

Measures to *strengthen the regulatory framework* refer, in the first place, to the limited array of energy policy means – as specified in the Renewables Directive 2009/28/EC [103]. First of all, a separate target for RE (next to a greenhouse gas reduction target) for 2030 helps to address the additional market failures that are associated with the deployment of RE. This should again be translated into National Renewable Energy Action Plans (NREAPs), which provide a clear guideline for Member State policies. In addition, the cooperation mechanisms established by the Directive – statistical transfers, joint projects and joint support schemes – would spur EU-wide RE deployment. So far, these mechanisms have only rarely been used for a variety of reasons [85,104–106]. Notable exceptions include the North Sea electricity grid founded in 2010 by nine EU States and Norway and the collaborative plans between Germany, Poland, the Czech Republic and the Netherlands to commonly manage fluctuating wind power [107]. Finally, the European Commission can make active use of the open method of coordination to promote voluntary convergence of Member State policies [99,108,109]. This method supports the exchange on experiences with and the performance of RE schemes across the EU – and may thereby stimulate regulatory competition and learning.

Beyond energy policy, the EU may also strengthen the regulatory framework in other policy fields for which it holds stronger competencies and which may have direct and indirect impacts on RE investment decisions [102]. First of all, this applies to the EU Emissions Trading Scheme (EU ETS, in line with Article 192 TFEU [110]), which, if tightened, could provide stronger incentives to switch to RE technologies. Second, minimum tax rates for fossil fuels and energy [111] could be increased to promote fuel switching. Third, the integration of the internal energy market (in line with Article 114 TFEU [110]) may be further promoted. Fourth, the EU could adopt more effective measures to support trans-European electricity grids (Article 172 TFEU [110]). In fact, Article 170 TFEU [110] emphasizes that such measures should pay particular consideration to connecting peripheral regions. Eligible measures include common guidelines to ensure network interoperability, a harmonization of Member States' diverse technical standards as well as the provision of financial support via the Cohesion Fund (Article 171 TFEU [110]). In this context, a strengthening of the competencies of the Agency for the Cooperation of Energy Regulators (ACER) as well as a stronger engagement of the European Network of Transmission System Operators for Electricity (ENTSO-E) may be desirable, particularly to allow for a more target-oriented planning of trans-European networks. A more transparent planning process could promote public acceptance of grid development.

4.2.2. *Financing an European energy transition*

Financing a European energy transition cannot be treated as an independent challenge to that of the political design of the energy transition. The counterfactual effects of not raising revenues can be substantial. In fact, Böhringer et al. [75] demonstrated that the overall employment and welfare effects are negative when an energy transition is financed by taxes on labor (or, to lesser degree, on electricity). This needs to be seen against a background of economic analysis that suggests that a shift from labor taxation to natural resource taxation could produce a double dividend by decreasing distortions in the labor market and making workers and employees better off, while at the same time incentivizing more efficient resource use [112,113]. This result co-aligns with more theoretical results pointing to the potential of rent taxation (e.g. land rent) to finance public goods without reducing market

efficiency [114]. Specifically, taxing GHG emissions could generate a climate rent that outperforms the counterfactual fossil fuel rent, generating a trillion $ revenue stream globally [115]. Hence, a primary source of funding of a European energy transition could come from within the climate change mitigation system, from taxing or pricing CO_2.

Within the European Union, the framework for generating a climate rent has been already established. Revenues are generated by auctioning ETS allowances. Resulting revenues are already used to redistribute funds to those Member States, which are least wealthy (10% of total revenues) or have realized most GHG emissions reductions (2% of total revenues). Both characteristics apply to many Member States in the south and east, and could be further extended to promote RE deployment in the periphery. For comparison, a hypothetical price increase of 20 €/tCO2 for emissions in the European energy industries would bring an additional revenue of about 30 billion € per year at 2012 levels of consumption. A fraction of about 1–3 billion € annually could help to reduce the barriers (soft costs in RE deployment; see Sections 4.1 and 4.2.1) and incentivize renewable deployment of a higher order of magnitude.

Other modes of financing could also be considered. Several European programs of financial assistance are already targeted to less wealthy regions in the periphery and/or the development of environmentally friendly energy technologies – including loans of the European Investment Bank and the European Investment Fund and means of the European Regional Development Fund and the Cohesion Fund. Specifically, the proposed expansion of loans from the European Investment Bank to leverage investments in recession countries [22] could be specifically directed towards RE deployment and similar investments to decrease energy dependence and mitigate climate change.

5. Conclusion

Our analysis substantiates Leggewie's claim [30] that an energy transition towards renewables in the Mediterranean region constitutes an important element towards a successful continuation of the European peace project and integration. Starting with climate change mitigation as a key objective, this paper argues that a European energy transition towards renewable energies is not only possible from a renewable resources point of view (Section 2), but could also help stabilizing national economies in the European South and other periphery countries (between 0.5% and 1% GDP increase possible), improve energy security (especially for Greece, Ireland and Italy), and possibly improve employment opportunities – depending on the assumed baseline macro-economic policy (Section 3). Economic justice considerations foster the understanding that a considerable part of required investments should be financed by economic-core European countries, which have benefited from the agglomeration dynamics of a unified European economic zone. While the overall evaluation is grounded in a broad cost-benefit analysis, a reduction in well-quantifiable outcome metrics would be misleading. In fact, if a European energy transition would show results, a renewed solidarity between European citizens could be the most valuable result even if hard to quantify in monetary or other economic units.

In the second part of this paper (Section 4), we analyze barriers and policy options towards realizing the benefits of a European energy transition. A key result is that barriers in many countries are combinations of economic and administrative obstacles: deployment costs, e.g. of photovoltaic systems, are often considerably higher than those in central European countries. Technology prices are dominated by world markets and do not cause this divergence. Rather, our analysis suggests that administrative procedures, often lengthy and complicated, but also lack of skilled labor capacity, and missing straight-forward financing schemes are at the center of the prohibitively high costs. Hence, a transfer of streamlined administrative procedures, labor skills, and financing schemes could support a country-specific acceleration of the learning curve, decreasing prices for renewables but especially solar. Overall, the policy analysis suggests that the country and even locality specific circumstances require member-state policies. European regulation and financing could then play an important supporting and coordination role. Crucially, a tighter cap of the European ETS would not only incentivize a faster transition to renewables, but could also serve as an important source of financing renewable deployment for cash-starved recession countries. Direct financial support could be focused on decreasing the soft costs of renewables, by streamlining administrative procedures and building up deployment capacity (training programs, financing schemes). Loans with low-interests rates from the EIB could leverage additional investments.

In summary, the analysis of this paper suggests that a climate-mitigation motivated European energy transition can also be understood as part of a strategy that counteracts the European recession and tentatively balances out its structural problems. The success of such a strategy must be seen with caution and depends on crucial implementation details. The advantage of providing a common rather than a fragmented European agenda, however, provides reason for optimism – a European energy transition could catch two European birds (climate change mitigation and relieving the deep recession) by one renewable stone.

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